These four, when they occur combined together, have long ago suggested the name of anvil cloud. Besides this classical form I may mention:

1. Cloud wedge.
2. Crescent.
3. Funnel.
4. Umbrella cloud.

Thus far I have made use of form only and have shown that all clouds may be fully described according to a uniform principle. But it is not the form only which has its story to tell; on the contrary, form tells but half the history of the cloud. If we desire to derive all the information possible we must take in the accidentals. These may be grouped under the following heads:

1. Condition.
2. Motion.
3. Distribution.
4. Color.

Condition:

1. Well defined. } Species or varities.
2. Ill defined. }
3. Stable.
4. Forming.
5. Breaking up.
6. In transformation: From—to.

Motion:

1. Slow.
2. Rapid.
3. Average.
4. Boiling.
5. End on.
6. Broad side on.
7. Aslant.
8. Direction whence.

Distribution:

1. Isolated.
2. Scattered.
3. Flocked.
4. Aligned.
5. Radiate.
6. Continuous.
7. Coalescing.

Color:

1. White.
2. Gray.
3. Blackish.
4. Red.
5. Yellow.
6. Green.
7. Iridescent, with.... as prevailing color.

The program of a single cloud observation will be, as follows: We are to determine, (1) the species and variety; (2) processes; (3) conditions; (4) elements of motion; (5) distribution; (6) color; (7) configuration of isobars.

The answers to the first six points are entered by means of symbolic signs in one column of a journal, and in a column parallel to this are to be entered the configuration of isobars, together with the state of the weather. Regarding the configuration of isobars, it is evident that most attention must be paid to that system under whose control the observer happens to be at the time of observation. The final and crowning work will be the collating of the two columns. These will in the course of time show repetitions, regularly recurring associations of cloud forms and type of weather, and *such regular associations are the expression of a law of nature:* they will form laws for the forecaster. By such method only shall we reach any practical results in cloud study. In way of consolation for those who find this method too elaborate or too difficult, I will quote a few lines from Clement Ley.[5]

All said then, and done, the land of clouds is not entirely one of fancy. The art of distinguishing and of usefully employing the distinctions between the varieties of cloud is not nearly so difficult as many an art in which the amateur engages himself for the sake of amusement, and a very cursory acquaintance with the labors of many writers—especially, if it is not insidious to say this of German and American writers—satisfies every one as to the fact that there is also a science of nephology, nascent though this science may be. How can practise and knowledge be most successfully promoted?

To this question, as put by Mr. Ley, I would answer: By systematic and detailed cloud observations; by attending to the so-called *trifles.*

[5] Cloudland, p. 201.

I might enter into some very interesting details myself, but since it is my object to show that cloud study, as a scientific branch of meteorology, is something more than noting one of 10 cloud forms opposite a given date, but I will close, hoping that some of the readers of the REVIEW will interest themselves in one of nature's most interesting languages and lend a helping hand in interpreting it and teaching it to others.

METHODS OF FORECASTING THE WEATHER.

A Lecture delivered by Prof. Dr. J. M. Pernter to the Association for the Advancement of Scientific Knowledge, Vienna, January 14, 1903. Translated from the Vorträge des Vereines zur Verbreitung naturwissenschaftlicher Kenntnisse in Wien. 43d Jahrgang, Heft 14.

Allow me to-day to address you once again on the subject of weather prophets, and this time to bring before you not only one or two kinds of weather forecasting, but to give you a more general survey of all methods at present in use, be they right or wrong, with or without results. I will keep strictly to the title of this lecture and give the prominent place to the methods of forecasting. I shall explain them and subject them to critical analysis, naming at the same time the advocates of each of the various methods; in the technical investigation, we have to do with the value of the methods and not that of the persons. I must, however, at once bring prominently forward the fact that we have at present, unfortunately, no method by which we can forecast the weather with absolute certainty even for one day in advance, to say nothing of longer periods. This is already self-evident from the fact that we are now able to speak of many methods of forecasting, whereas if there were a sure and infallible method, then it would be out of place to speak of the other methods to this society for the advancement of scientific knowledge.

All methods of weather forecasting, not excepting those in use by the central meteorological offices, are based upon observed weather conditions and have, therefore, an empirical foundation. Many of them do not even make the slightest attempt to put their methods on a theoretical basis and content themselves with setting up "weather rules." Even the scientific methods of professional meteorologists have not yet succeeded in deducing a theory capable of determining in advance the changes of the weather as the effect of one or several known causes. Only the advocates of the influence of the moon have ventured solely by means of aprioristic theories to "calculate" the weather for long periods in advance.

There are many widely different methods by which the various classes and kinds of weather prophets carry on the work of weather forecasting. There are those who make use of the behavior of animals to foretell the weather; hunters who recognize the character of the approaching season from the actions of the wild animals; the observers of birds, spiders, crickets, ants, and other animals from whose conduct they judge of the approaching weather. But in addition to this class which utilizes living animals there is another opposing class that prefers to make use of the dead substances of the animal or vegetable kingdoms, such as hairs, strings of instruments, roots and fibers of plants; by means of their expansions or contractions, either with the aid of little weather houses and figures or without them, they recognize the coming weather. Others prefer to consult stones and walls as to the character of the weather to be expected, and turn rather to inorganic nature in order to learn from the "sweating" or dryness of these whether to expect rain or continued fine weather. Thus, as you see, all the kingdoms of nature are drawn upon to furnish prognostics of the weather, and it may depend upon the occupations and predilections of the various persons interested in the coming weather whether they give the preference to one or the other. But I had almost forgotten to mention another class—perhaps the largest—those who are not to be satisfied by any one of the three kingdoms nor even by all three together, and who rely only on

their own bodies for foretelling the weather—assuming, of course, that these have nerves, joints, and corns; sometimes it is the stomach and sometimes even the head that is made use of. I am not joking in the least; on the contrary the persons inclined to this kind of weather forecasting excite my sincere commiseration.

If these classes of weather prophets who undertake to foretell the weather by the sensations of their bodies, by observations of the animal and vegetable kingdoms, and even by the processes of inorganic nature, always rely upon facts which may have a distant connection with the weather, yet, they are still far behind that class which forms its conclusions of the approaching weather from observations of the weather conditions themselves. You are all well acquainted with this latter class of weather prophets; in every community there is at least one person who is especially relied upon, whether he be a farmer, a miller, a teacher, or a pastor of long standing. They look up at the sky, observe the clouds and the direction of their motion, and from these they forecast the weather for the next day, with good results. These local weather prophets rely indeed upon phenomena which have the closest connection with the coming weather. For the weather does not spring like a Deus ex Machina down from a distant cuckoo's nest in the clouds, but is drawn from comparatively near regions, or if you prefer, forms gradually in the place itself. This coming, this formation of the weather is announced by the appearance of the sky, sometimes for a longer, sometimes for a shorter time in advance, and the skill of the weather prophet consists in rightly interpreting, for the near future, the appearance of the sky and the weather conditions. Since it is generally necessary, in order to grasp the weather conditions correctly, to have a clear judgment founded on long experience in observing, together with an accurate eye and, I might almost say, an inborn quickness of perception, therefore, there are, as a rule, only single individuals in every community who enjoy the reputation of being good weather prophets. Certain phenomena, however, are of so typical a nature that they have been reduced to fixed rules and are everywhere expressed in popular language.

Thus every country has its weather signs; if the clouds are increasing, a storm or continuous bad weather is approaching. In every locality there is one direction of cloud motion that betokens bad weather, and another, generally the opposite direction, which portends fine weather, etc. Weather rules relative to the red morning and evening sky have been deduced. The rules that bad weather is expected when in any given locality the summit of a certain mountain is covered with a cap; that a small "watery" halo around the moon indicates rain; that the weather will continue bad if, when the clouds break up, a second light covering of clouds is seen above them; that it will be fine weather if, after rainy weather, according to the locality, a certain wind sets in; that a slow breaking up of the clouds gives promise of fine weather, etc.; all of these rules have been formulated from long-continued and accurate observation and are exceedingly well adapted for local weather forecasts from one day to the next. Experienced observers also know from the color and nature of the clouds whether the prevailing weather, notwithstanding otherwise favorable indications, will continue or will change, and by these delicate distinctions they generally acquire the reputation of being especially good weather prophets.

These observations of weather signs led the way, however, to more far-reaching rules which included the attempt to determine from the weather conditions at a certain season of the year what they would be for a long series of days; or, to determine from the weather of a season, or of a certain day, or a fraction of a day, the conditions of an approaching season. Thus originated the so-called "farmers' rules," among which are some valuable ones based upon good observations extending over a hundred years, but in contrast to these there are, unfortunately, many poor ones for which we are indebted to the superficial and frivolous rules manufactured by speculating calendar makers.

Others, however, went still further and, from observing that the weather of one year resembled that of a former year, concluded that there is a certain regularity in the recurrence of years with similar characteristics, and that they were justified in enunciating the law that almost exactly the same weather returns at intervals of eleven, or of eighteen or nineteen years, so that it would only be necessary to expect in the coming year the weather observed a certain number of years before. It is evident that this would be the simplest method for predicting the weather in any year, day by day or at least week by week, and this is the system followed in the so-called "hundred-year calendar." Unfortunately the facts do not agree with the predictions.

Both the methods above named in general endeavor to keep one free from preconceived ideas as to causes, and base their predictions of the weather only upon earlier observations and experience, often supported by records of the weather actually prevailing, whether made with or without instruments. There are other prophets who have sought for the cause that dominates the weather and weather changes and adopting this when found have made their weather predictions in accordance with the properties, movements, and changes of this accepted cause.

This latter class, somewhat precipitately and without sufficient experience in the principles of observational work, but driven by the innate longing in the human breast to seek for a cause for all matters and supported only by general a priori considerations has sought for the dominating cause of the weather. Thus, from the consideration that the sun dominates everything on the earth Professor Zenger has chosen that as the agent of the weather changes, which he ascribes to the rotation of the sun on its axis. Now, since the time required for a revolution of the sun occupies about twenty-six days, he has chosen one-half of the time of a revolution, that is to say twelve to thirteen days, as the period by which he measures the changes of the weather, and has arranged a weather calendar according to which there is a day of disturbance every twelve to thirteen days. In the interval between the two days of disturbance there is an interval of safety or what he calls "calms." The comparison of the predictions of the "days of disturbance," and "days of calms," with the weather actually occurring is supposed to give the proof of the correctness of the assumption that the semirotation of the sun governs the weather. Up to the present time, however, this has not yet been accomplished, for the attempted demonstration has entirely failed.

The method of weather predictions proposed by Professor Servus is of a similar character; he considers the interior of the earth, and from the fact that the attraction of the earth upon the atmosphere attaches the latter to the earth, he argues that "all the great disturbances in the equilibrium of our atmosphere are caused by changes in the condition of the interior of the earth, which produce disturbances in the power of attraction." You will see at once, without further explanation, that this is not a tenable principle for weather predictions: Servus himself, for the purpose of preparing weather predictions, has been obliged to call in the sun and moon to his aid as causes of the disturbance in the condition of the interior of the earth. In this way his method approaches so nearly to that of Zenger and those of the lunar prophets that we need not treat of it separately.

But Professor Lamprecht has shown us in a most startling manner how far one may be led away by adopting a priori causes for the changes of weather without a sufficient basis of experience. By analysing a series of observations for several

years he has discovered five periods in weather processes, one of $12\frac{1}{9}$ days, one of $12\frac{23}{30}$ days, one of $13\frac{9}{11}$ days, one of $14\frac{3}{4}$ days, and one of $29\frac{3}{7}$ days. Before passing on I must just tell you that one can, according to his method, compute periods of almost any length desired. This is not objectionable; but he now proceeds immediately to find the causes for these periods, which were really only computed and not at all furnished by experience, and, since he sincerely wished it, he found them. We can only be astonished at the boldness of his hypothesis. He assumes the earth to be surrounded by five rings, similar to the rings of Saturn, and that their periods of rotation and temporary relations to one another are the causes of his weather periods. Lamprecht represented to himself the existence of these imaginary rings in such a manner that he immediately endowed the rings with names, giving them successively the following magnificent names: Emperor William ring, Moltke ring, Bismarck ring, Copernicus ring, King Albert ring.

An old and by far the most widespread method of weather prediction is based on the idea, which is I might say universal among mankind,[1] that the heavenly bodies have an influence on everything which takes place on the earth, and particularly upon the weather. The moon is that one which was supposed to more especially influence the weather, although this power was attributed to the planets also, so that each one produces a certain kind of weather, and therefore divides the year into damp, dry, stormy, quiet periods, etc., according as one or the other planet is the "ruler for the year." The moon is credited with being the principal dominator of the changes of the weather. The weather is supposed to change by preference with the moon; therefore the new moon and the full moon especially possess the power of influencing the weather, and one of the most widely spread weather rules is that the weather changes with the new moon and the full moon. However, the first and last quarters are considered of greatest importance by a great many. Especially clever observers of the influence of the moon upon the weather pretend to have also observed the distinctive individual influences of the phases known as octants. In general the opinion is very widespread that the decreasing moon exercises a weak and the increasing moon a strong influence. Thus far the theory of the influence of the moon on the weather is the direct result of the popular belief in the moon, without regard to any scientific basis.

I am not able to state whether the growth of this popular belief was preceded by observations of the weather changes, and is therefore to be regarded as a result of observations (it is not a question here as to whether the latter were defective and inconclusive or not) or whether, on the contrary, the belief in the influence of the heavenly bodies and in that of the one which, after the sun, appears the largest and most striking to mankind, namely, the moon, was the earliest step, and that it was in the light of this belief that observations were first made. At all events the latter is far more probable than the former, and, therefore, I can not put the moon theory of weather predictions in the same category as the methods mentioned in preceding paragraphs. These latter methods were certainly based on observations (we say nothing as to whether the observations were correct or not); but this is not established in regard to the belief in the moon theory: indeed the probability is in favor of the contrary process, namely, the opinion that the moon must influence the weather came first, and observations only came later in order to see if the theory were correct.

This idea is strongly supported by the more recent development of the theory of the influence of the moon upon the weather. This newest and at the present time very prominent phase of this theory did not start by collecting reliable observational data and deducing from these observations the influence of the moon, upon the weather, but first adopted the old belief in the moon and then sought to create for it a scientific basis by means of a priori assumptions and even theoretical mathematical explanations.

With these results, either assumed or computed, the representative of the modernized theory of the moon appears before the public and invites his contemporaries to test his "results" by observation. This process is, as you see, the exact opposite to that of the true empirical method. The empiricist makes observations, observes long and much, and sums up the general results of the observations in certain propositions or "rules," and when it is possible, draws his conclusions as to the cause of the phenomena. The modern moon prophets turn the process upside down. They designate the moon beforehand as the cause of the changes of the weather; from the various positions of the moon with respect to the earth and the sun, with the assistance of the laws of attraction—without any strict investigation as to how far these can possibly be of influence—they compute the attraction exercised by the moon in its separate positions, and say on such and such a day the influence of the moon must have produced such and such a result on the weather. The confirmation of these predictions by the observations should then only show the accuracy of their assumptions and computations. The number of these modern moon prophets is at present large; many of them take into consideration the planets in addition to the moon. The names of the most prominent advocates of these moon theories are known to you. They are as follows: Falb, Ledochowski, Gladbach, Demtschinski, Garigou-Lagrange, A. Poincaré—not the celebrated mathematician—and Digby.

It would be quite erroneous if this method of investigation into the causes of the weather were regarded as incorrect and improper. By this presentation of the subject I wish only to show that the modern moon prophets—and probably also the older ones—have not introduced strictly inductive empirical methods into their belief in the moon, but that this belief was there from the first and that they have made use of the discovery method for its confirmation, since it is on the basis of the moon theory, or, if you prefer, of aprioristic considerations as to the influence of the moon, that they make their weather predictions, and then from the agreement between these they endeavor to deduce the correctness of their assumptions. Against this method as such there is nothing to be said, but it demands the most conscientious, straightforward, logical, and accurate determination of the consequent weather if we wish by this method to arrive at a confirmation or refutation of the propositions advanced as to the influence of the moon. How this is to be managed we have still to learn; meanwhile it is at present only necessary, in this enumeration of the various methods for predicting the weather, to include that one which represents the influence of the moon.

As soon as men began to observe the barometer attentively, they began gradually to recognize that the rising and falling of the barometer had an evident connection with the weather. It was the celebrated burgomaster, Otto von Guericke, of Magdeburg, who first used the barometer as a "weather glass." He applied, even then, to his water barometer the "weather scale" which is at present in such general use, on which the highest reading occurring at any place is designated as "Fine Weather," the lowest reading as "Rain and Wind," etc. The barometer as a weather glass has taken its course throughout the world and is, to-day, used almost universally. After the introduction of the aneroid barometer the "weather scale" was also affixed to that and whoever purchases such an instrument pays particular attention to make sure that the

[1] Astrology seems to have been specially cultivated in Mesopotamia and to have been spread north, south, and west by Sanskrit, Greek, and Arab influences. It is peculiarly Asiatic and European. There is no record of its having had any great influence among the Chinese, Malays, or American Indians. It can, therefore, hardly be spoken of as universal among mankind.—ED.

weather scale is correctly fixed on it. The makers of these instruments must know the mean pressure at the dwelling place of the purchaser; there they place the term "Changeable;" the point where the pressure is about 10 millimeters above the mean is "fine," and at about 20 millimeters above the point designated as "changeable" will be "steady," "fine," or "dry," or the like. At about the same distance below "changeable" is placed "rain" and storm."

Whoever has provided himself with an instrument of this kind believes himself to be the possessor of a self-registering weather prophet and is generally highly indignant if it rains when his barometer stands at fine, or astonished if it is fine weather when the barometer says rain. Since these erroneous indications are not unusual with the barometer, therefore faith in it as an indicator of the weather is very much diminished and is only maintained at all, on the one hand, by the fact that the barometer frequently "indicates correctly" and, on the other hand, by force of habit. Frequently, however, one has taken refuge in another instrument, namely, the hygrometer. This instrument shows only the amount of moisture actually prevailing in the air, in the same way that the barometer indicates the actually prevailing pressure. As the pressure and the moisture are both connected with the weather, the hygrometer may be used as a weather prophet in the same way as the barometer, although that is not its real vocation. If the hygrometer shows a high degree of moisture, that only indicates that the air is just then very moist, and this generally happens only when the weather is already bad. However, it happens sometimes that the moisture in the air increases while the weather is still fine, so that the hygrometer then indicates approaching bad weather. In the same way, the hygrometer will generally indicate dryness when the weather is fine; it will sometimes, however, when the weather is not yet fine, point to decreasing moisture, and thereby foretell approaching drier and finer weather. The best of these hygrometers are made of human hairs, divested of grease, which have the property of being expanded by dampness and contracted by dryness in a most admirable manner. This property of varying its dimensions with the changing moisture is also possessed by other animal and vegetable substances. There are a number of weather indicators of this kind, among which the little house with the little man and woman, in which the man goes out in bad weather and the woman in fine weather, is probably the best known.

The discredit into which the hygrometer, as a weather prophet, has often fallen, is as easily understood, as in the case of the barometer. Its duty is only to show the moisture actually prevailing at its locality, and this knowledge does not enable one to make determinations of the approaching weather any more accurately than does a knowledge of the pressure at any place.

A new, and we must at once say, a truly empirical method of weather prediction is that at present in use by all the official central meteorological establishments in the world. This method has gradually and slowly developed according to the exact rules of investigation in scientific practical meteorology, and is still far from having reached perfection. It has developed entirely, without any addition of an aprori nature, out of the observations of the weather processes, and is, therefore, based entirely upon well established observational data. The most fundamental of these facts is that the weather is associated with the distribution of atmospheric pressure. It has been recognized more and more clearly by experience that the weather is determined, not by pressure as shown by the barometer at the place of observation, but by the barometric conditions that prevail over vast regions—for instance, those distributed over the whole of Europe. Therefore, one must chart and study the distribution of atmospheric pressure over the whole of Europe if one wishes to understand the weather actually prevailing.

It was necessary, first of all, to determine by extended observations, made as nearly simultaneous as possible, the distribution of atmospheric pressure for a definite hour, in order to perceive to what kind of weather this distribution of atmospheric pressure corresponded. It was by this means demonstrated that there is an extraordinarily great variety of forms of atmospheric pressure distribution; that these, however, can be classified into a certain number of types by having regard to the form as well as to the weather conditions given in these forms. Allow me to illustrate, by some of the cases before us on these charts, the manner in which this study of the relation between the distribution of atmospheric pressure and the weather has proceeded, a work that is at present being still further carried on.

Figs. 1 to 8 present the principal types[2] of the distribution of atmospheric pressure over Europe. They have been chosen in order that we may observe those types which influence the weather in Austria. Here we find the distribution of atmospheric pressure grouped, on the one hand, according to the location of high and low pressures over various regions of Europe, and on the other hand, according to the forms of the isobars. These are not average or ideal charts, but each one reproduces the distribution of pressure actually observed from 7 to 8 o'clock in the morning of a certain day. We have here before us the following types:

(*a*) Weather map for September 22, 1895. Region of high pressure central over Europe, gradually diminishing in all directions.

(*b*) Weather map for January 3, 1894. Region of high pressure over the north of Europe, region of low pressure over the Mediterranean Sea.

(*c*) Weather map for February 23, 1892. Region of high pressure in the northeast, or northern Russia, region of low pressure over the Atlantic Ocean in the west.

(*d*) Weather map for January 10, 1899. Region of high pressure in the southwest over the Balkan Peninsula, region of low pressure in the northwest.

(*e*) Weather map for November 26, 1888. Region of high pressure in the south over the Mediterranean Sea, region of low pressure over the north of Europe.

(*f*) Weather map for January 30, 1892. Region of high pressure in the southwest over Spain, region of low pressure over the north and east.

(*g*) Weather map for October 17, 1895. Region of high pressure in the northwest over England, region of low pressure in the east and southeast.

(*h*) Weather map for May 16, 1895. Region of high pressure in the west and east, region of low pressure over the whole of middle Europe from the north to the south.

These selected charts are representatives of the most important styles or types of the distribution of atmospheric pressure upon which our weather depends. The thorough and persevering study of the weather that prevails on the occurrence of each type has led to the definite and certain recognition of the following theorems:

1. The weather, in all its details, depends upon the distribution of atmospheric pressure, and the same weather always corresponds to the same location relative to this distribution.

2. The weather of any place is, therefore, determined by its position in, and relation to, the various styles of pressure distribution.

3. If we succeed in knowing in advance what distribution of atmospheric pressure will prevail on a certain day, or on a series of successive days or a longer season, then the weather of the day, or of the period of time, is thereby determined in advance.

[2]The maps are omitted in this translation, as analogous American types are to be easily found.—ED.

4. The modifications introduced by reason of geographical conditions, the configuration of the ground, as for example, the location of a place in the Alps, etc., are constant for the location in each style of pressure distribution.

By means of these theorems, which were deduced from exact observations, the foundation was laid for a careful method of weather prediction. Two things were now necessary: (*a*) The perfecting of our knowledge of the typical distributions of atmospheric pressure and of the details of the weather attending them; (*b*) the deduction of the rules, according to which one form of distribution of pressure either remains stationary, or moves over Europe, or changes into another form, or is pushed aside by some other type.

It is in the nature of things that the first task is more easily accomplished than the second. The present state of the art of weather prediction in our central meteorological institutes corresponds to this condition of affairs. The details of the weather conditions within the various styles of pressure distribution are, on the whole, quite well known: however, there remains much to be done in this direction, and it is now one of the most important duties of meteorology to most thoroughly investigate, in all directions and details, the distribution of the weather according to the forms of pressure distribution. The knowledge of the weather conditions for every place and for every type of pressure distribution offers the only entirely satisfactory empirical basis for weather predictions; moreover, it is by this knowledge alone that we can hope at some time to discover the fundamental laws of the changes in the weather. This knowledge, however, does not lead us immediately to a prediction of the approaching weather, but only teaches us to know the weather of one particular place when the distribution of pressure is known. In order to be able to predict the weather, we must know one thing more: we must know in advance what distribution of atmospheric pressure will prevail at the time for which we are predicting the weather. This foreknowledge of the pressure distribution is the starting point upon which the whole weather forecast depends. If this foreknowledge of the future distribution of atmospheric pressure is impossible, then weather prediction is impossible; if we can foretell it approximately, then a weather prediction of greater or less probability is possible, and we shall be able to make a larger number of correct than of incorrect predictions; if the distribution of atmospheric pressure can be known in advance with certainty, then we shall be able to make weather predictions with certainty.

Now, how do we stand as to the question of certainty in foreseeing the approaching distribution of atmospheric pressure? If we knew the laws according to which one distribution of atmospheric pressure changes over into another, or according to which it moves across Europe, as well as the laws that cause one distribution of atmospheric pressure to continue stationary or suddenly break up and another one result from from it, then the problem could be solved and future weather could be predicted with entire certainty. We should proceed with mathematical accuracy in the prediction of weather, and be able to attain the correctness of the astronomers in their predictions of celestial planetary motions and phenomena. This of course, is the ultimate aim of meteorological science, but we are at present so far removed from it that we have may well founded doubts as to whether this object will ever be attained. Up to the present time we are only able to deduce from the experience hitherto acquired a few empirical laws of limited applicability, according to which the types of distribution of atmospheric pressure remain stationary, change, or transform themselves entirely, or perhaps move away over the earth; even this limited empirical knowledge relates almost entirely to the change from one day to the next. Since these empirical laws as to the changes in the distribution of atmospheric pressure are so defective the difficulty of foreseeing the approaching distribution of pressure is correspondingly great, and the prediction of the weather even for the next day is proportionately unreliable. Since we have to do only with theorems founded entirely upon experience, the persons best qualified to make the predictions are those who through long years of practise have collected the most theorems as to the variations in the forms of pressure distribution, and have also learned by practise the many modifications to which these theorems are subject. In the forecasts for the next day men of much experience attain to more than 80 verifications in a total of 100 predictions; but the prediction of the distribution of pressure for more than one day in advance has such a low probability that in a forecast of the weather for several days in advance we must expect more failures than results.

You will say: "It is despairingly little that we have to expect from scientific weather predictions, and hence it is not to be wondered at that the public generally clamors for methods that promise more." It is easy to promise, but one's promise must be kept, and that is difficult. It would also be easy for scientific meteorologists to make the same promises and boastings as the other weather phophets, but they would then cease to be called scientific. And of what use is it to cling to those weather prophets who certainly promise a great deal, but finally leave you in the lurch? Of the popular methods of predicting the weather above enumerated, none accomplish nearly as much as is accomplished at present by the scientific method; indeed, very often they accomplish nothing beyond the noise they make in praising themselves. However, before I begin to criticize the various methods, I will briefly lay before you the processes adopted in weather prediction at the central meteorological stations. You know that at our Central Office in Vienna, for example, telegrams arrive every morning from more than 140 places over the whole of Europe; these telegrams contain the observations made that morning of pressure, temperature, moisture, precipitation, and wind. According to these telegrams the chart of the distribution of atmospheric pressure is drawn as it prevailed over Europe that morning; and from this particular style of distribution of atmospheric pressure in conjunction with that which prevailed on the preceding day, and by making use of the above-mentioned empirical laws governing the changes in the forms of the pressure areas, a tracing is made of the probable areas of atmospheric pressure for the next day. When this sketch is completed, then the predictions for the various portions of the kingdom are made upon the basis of our knowledge of the weather conditions at different points of each area of atmospheric pressure. Thus, the primary difficulty consists in forming a correct conception of the pressure distribution for the next day, based on that prevailing on the morning of the day in question, and at the same time a clear idea as to the velocity with which the changes will proceed. In order to facilitate this difficult task the Central Office receives immediately before the making of the forecast, which takes place at 1:30 p. m., a short telegram from twelve selected stations in Austria-Hungary, giving the latest information as to changes in temperature, pressure, and cloudiness that have occurred at these stations since the morning observation. From this last item we can perceive with more certainty whether we have formed a correct idea as to the distribution of atmospheric pressure for the next day or not and, therefore, whether to retain or modify the forecast. It is only after the data of the midday telegrams have been made use of that the definitive forecast is made. At 1:45 p. m. the weather report goes to the printer and the corresponding telegrams are sent to those who have subscribed for the daily telegraphic forecasts.

The results of this system of honest weather forecasts are indeed modest, but are such as to show a real and striking progress in weather predictions as compared with other methods. Of course even this earnest scientific method allows

us only to consider the general characteristics of the weather as, for example, "fine," "windy," "mild," "fine and cold," "cloudy," "rainy," "warm," etc., as the object of the weather forecast. This method would immediately supplant all others if it would undertake to foretell the duration and amount of precipitation, the degree of the thermometer, the exact force of the wind, etc. However, we may at present be very well satisfied if the general character of the weather is predicted for us. Unfortunately, even the scientific method can give us no positive certainty, since even by confining itself to these general characteristics it can at present offer only a little above 80 per cent of verifications of the weather.

In this state of the case it is self-evident that our efforts are to be guided in the direction of those studies that will lead us to an ever increasing accuracy in forecasting. These studies of course relate (1) to more and more thorough investigations of the weather conditions at every point and in every phase of the distribution of atmospheric pressure; (2) to the discovery of signs by which to form a judgment (*a*) as to the rapidity and paths with which each type of pressure distribution moves over Europe; (*b*) into what other forms a given type of distribution transforms itself and the rapidity of such change; (*c*) what changes in the weather attend the various modifications of one and the same type of atmospheric pressure distribution. With the increase of our knowledge on these points the weather predictions will also become more and more accurate; however, it is very doubtful whether it will ever be possible for us to invariably attain absolute accuracy even for one day in advance. Every increase in the percentage of verifications is, however, of the greatest value, especially to national economics.

Now, as a matter of course, the meteorologists are looking everywhere in order to take advantage of everything which may be of assistance to them in this matter. In the first place there are the many good weather rules that have been deduced from the experience of many hundreds of years. But the greatest number and most valuable of these weather rules are only applicable to local weather predictions, whereas the central meteorological institutes must make their predictions for very distant countries also, as for example, Austria for Dalmatia, Vorarlberg, Bukowina, etc.

Those weather rules, however, which relate to the weather conditions of certain definite dates and which are generally looked upon as farmers' rules are sometimes of great assistance in making forecasts. Thus, we know that on certain dates of the year there has for centuries been a tendency to a certain kind of weather; for example, to rainy weather. Therefore, if at such periods the distribution of atmospheric pressure is of such a form that it may easily change to a type corresponding to the weather indicated by the farmers' rules, then we may be tolerably certain that we must forecast wet weather. But, on the other hand, if at some such period the distribution of pressure is of such a character as would ordinarily justify us in hoping for a change of weather, still we know that this change is not likely to occur, because there is a continued tendency at this period to wet weather and a change of weather is not to be looked for. Such aid as this from farmers' rules is, however, of moderate value and rarely available. But it is quite otherwise, in the opinion of the believers in the moon, when we consider the support that the weather predictions might derive from hypotheses that attribute to the moon and the rest of the heavenly bodies a decided influence on the weather. I will express myself more in detail on this subject.

First and foremost, I must insist most strongly on the fact that professional meteorologists themselves have always recognized and do recognize one influence of one heavenly body as most decisive and the sole cause of the weather on our earth, viz, the heating of the earth and of its atmosphere by the sun. The sun regulates our weather; it gives rise to winter and summer; by evaporation it raises the aqueous vapor into the air, and this vapor, by cooling, produces clouds and rain, snow, storms, and hail; it is the primary cause of the differences in atmospheric pressure, and in this way produces the winds.

This heating influence of the sun, as also its modifications by cloudiness, by the wind, by the change from day to night or from winter to summer, and by the properties of the earth's surface, which, consisting as it does of water and of land either covered with vegetation or barren and bald, has varying capacities for absorbing the sun's heat—this influence of the heat of the sun has been established with the most absolute certainty by the most exact observations. It has been demonstrated to be so much more important than any other cause, if any such exists, that up to the present time it has not been possible to recognize any other cause with certainty, in spite of the fact that the professional meteorologists, and singularly enough they only, have instituted extensive and most thoroughly exact investigations in order to discover such other influences, in case there are any, and to determine their value. And what has been the result of these extraordinarily laborious and wearisome investigations? Before I answer this question I must call your attention to the fact that not one of the representatives of the theory of the influence of the moon, or of any other cosmical influence, has undertaken to give an unobjectionable, rigorous demonstration of such an influence. These gentlemen content themselves with the inventive method and apply it in a very singular manner. They make their predictions for certain days and always call attention to the cases when they are successful, but never trouble themselves about the failures. Now I beg you to observe that in every game of chance where there are but two alternatives there must occur 50 verifications out of every 100 guesses, when a great number of guesses are made and it is all pure chance. The time at which the game of chance is played, or the time when the guess is made is absolutely without any influence whatever upon the result. So, also, the drawing out of an even or uneven number of balls could have no influence upon the weather even if it should occur to some one always to predict fine weather when he drew an even number and bad weather when he drew an uneven one. If, therefore, one should make use of the above mentioned inventive methods, he should carefully record all the cases, the failures as well as the verifications. And then, even if every second case is a success—that is to say, even if he obtains 50 per cent of verifications—he will know that the theorem or assumption made use of as the basis of the predictions really has no causal connection with the weather. Only when more than 50 per cent of verifications are attained can the argument favor the assumption, and so much the more in proportion as the verifications exceed 50 per cent.

This exact method, the only one for testing their hypotheses as to the cosmical influences on the weather, is the one that has never been applied; in fact it has often been distinctly rejected by those who maintain the existence of these influences; and yet those who make assertions should prove them. It was the professional meteorologists themselves who undertook the accurate examination of all the various cosmical hypotheses, and particularly that of the influence of the moon, and it was they who found a slight influence of the moon on storms, thunderstorms, the direction of the wind, atmospheric pressure, etc. Now, do you say, "I told you so?" Well, first of all observe—and I can not insist upon it too strongly—that it is the professional meteorologists, and they alone, who have made these investigations which point to a slight influence of the moon. Next, I must direct your attention to that little word "slight." The influence thus discovered by them is indeed so small that we can not even state with certainty whether it really does exist at all; or whether, perhaps, it was only perceptible in these investigations because the period of time included in them is still too short to furnish us with an

unexceptionable result. However, let us assume that this slight influence really does exist, and let us examine the amount of this influence a little more closely. Its magnitude is expressed by the percentages of the favorable cases. We will, however, for once greatly exaggerate and assume that these favorable cases amount to a surplus of 5 per cent. That is to say that in 100 cases 55 succeed and 45 fail. Now, if you use such lunar rules for weather predictions, what does it advantage you in isolated, single cases? For instance, you are in doubt as to whether the rain is to be expected or not; the influence of the moon indicates rain with a weight of 0.05. In spite of this small weight, if now you forecast bad weather, you will, if 100 such cases occur, have a failure in 45 cases. Had you paid no attention to the influence of the moon, you would possibly have had 50 failures. Thus, in this case of 5 per cent of surplus, that would be the whole effect of your consideration of the moon's influence. But we have in fact assumed an exaggerated case, and the real influence of the moon is in every case less than one-half of this, if indeed it really exists at all.

You may rest assured that the professional meteorologists accept, nay even seek for, everything that can give them any assistance whatever in their weather predictions. By constant investigation and study we may hope to advance step by step, and per cent by per cent. Every single per cent of agreement that is gained is an important advance and success.

KITE FLYING IN THE TROPICS.

By OLIVER L. FASSIG, dated Baltimore, Md., December 25, 1903.

On June 1, 1903, an expedition under the auspices of the Geographical Society of Baltimore, directed by Dr. George B. Shattuck, Secretary to the Society, left Baltimore on the two-masted schooner *Wm. H. Van Name* for the Bahama Islands. The purpose of the expedition was to make a scientific survey of the islands along the lines of geology, physiography, botany, climatology, terrestrial magnetism, marine life, and tropical diseases. The scientific staff, comprising 25 members, was selected largely from men at one time or another connected with the Johns Hopkins University and from representatives of several of the scientific departments of the United States Government.

Included in the equipment for a study of the climatological conditions of the islands was a complete outfit for investigating, on a small scale, the conditions of the upper atmosphere, loaned to the director of the expedition by the Chief of the Weather Bureau. This outfit consisted of one medium-sized and one large box kite, two meteorographs, a hand reel with 15,000 feet of steel piano wire, and a nephoscope for altitude measurements. In addition, the instrumental equipment included a Richard barograph, a thermograph, and a hygrograph, a sling psychrometer, a rain gage, and a rain recorder, the property of the Maryland State Weather Service. Provision was also made for observations of ocean surface temperatures from Baltimore to Nassau and return, for tide observations, and for a magnetic survey of the islands by the writer, the results of which will be published later. The present report is confined to a discussion of the results of kite flying at Nassau, the principal town of the Bahama Islands.

Head winds and rough weather caused considerable delay and inconvenience on the outward voyage, and the expedition did not reach Nassau until the 17th of June. Through the courtesy of Mr. Flagler, the use of the grounds and clubhouse connected with the Colonial Hotel was kindly granted for the kite experiments. These grounds were by far the most suitable place to be found in the vicinity of Nassau for the purpose, being one of the few open stretches of field upon the entire island. Situated west of the town of Nassau, along the northern coast of the island and just below the ruins of old Fort Charlotte, the field afforded a free sweep of the air in the direction of the prevailing easterly winds of these latitudes. The Island of New Providence, upon which Nassau is situated, is a small island, measuring less than 20 miles from east to west and about 7 or 8 miles from north to south at its widest point. It lies about 150 miles to the east of the southern point of Florida, in latitude 25° north, longitude 77° 30′ west, along the northern edge of the trades.

Several days were spent in unpacking and mounting the meteorological, magnetic, and tide instruments, and the kites, and in waiting for favorable winds. It was not until the 27th of June that the wind seemed of sufficient strength to warrant an attempt to raise a kite. At this season of the year winds above 10 miles per hour can not be counted on daily, excepting for short periods. Beginning at sunrise with a breeze of 5 or 6 miles from the east-southeast, the strength increased by noon to 8 or 9 miles, with occasional higher velocities, but seldom exceeded 15 miles per hour.

To one accustomed to the rapid and extreme fluctuations of temperate zone weather, the tropical conditions appear monotonously uniform; clear skies with intense sunshine, a few patches of loosely formed cumulus clouds, an occasional shower of short duration, a small range of the thermometer, generally, at this season, keeping within the limits of 80° and 90°, these are conditions which may repeat themselves day after day for long periods. Though the direct sunshine is intense, the atmosphere is not excessively oppressive, being moderately dry, and seldom stagnant. So far as personal comfort is concerned, these conditions are less trying than the warm, muggy days of the coastal plain of the Middle Atlantic States. In these islands there is generally a sufficient breeze for comfort when not exposed to the direct rays of the sun; from the warm moist and stagnant atmosphere of the Middle States there is often no escape, even under the shelter of roof or tree.

A preliminary flight was made on June 27, between 11 a. m. and 1 p. m., using the smaller 7-foot kite. The wind was east-south-east, and blowing with a velocity of about 10 miles per hour. No effort was made to reach any considerable height, the main purpose being to test the kite and apparatus. The maximum elevation was slightly over 1000 feet.

In all of the experiments conducted at Nassau, the kite meteorograph was checked by means of an aneroid barometer and a sling psychrometer at the surface just before the kite was raised, and at short intervals until the close of the flight. In addition, the barograph, thermograph, and hygrograph were installed in the Nassau Cable Office, about three-fourths of a mile distant, by the courtesy of Mr. P. H. Burns, Superintendent of the Bahama Cable; these instruments in turn were checked frequently by means of eye observations of the thermometers and mercurial barometer at the Cable Office.

On July 1 the kite was raised at 10 a. m. and not lowered until nearly 5 p. m. The wind was east-southeast, with a velocity of 15 miles, until 1 p. m., when the velocity fell to 11 miles, which was maintained until the end of the flight. The day was marked by an unusual amount of cloudiness, varying between five and seven tenths, mostly cumulus, with a few alto-cumulus. A light scud occasionally passed under the kite. On several occasions the kite was entirely obscured, being sometimes in the passing cloud, and sometimes above it. The greatest elevation attained was about 2600 feet at 12:23 p. m., with a temperature at the kite of 69°, and a surface temperature of 83°. The atmospheric pressure, as registered on the kite meteorograph, was 27.60 inches, and at the surface 30.03 inches. It was with considerable difficulty that the kite was maintained at the higher elevations. The tracings of the kite meteorograph, (see figs. 1, 2, 3), show constant fluctuations, doubtless largely due to frequent reeling and unreeling in attempts to increase the altitude of the kite, but in a measure also to be attributed to variation in the strength of the wind.